

Vertically-guided Instrument Approaches Using the Wide Area Augmentation System (WAAS)

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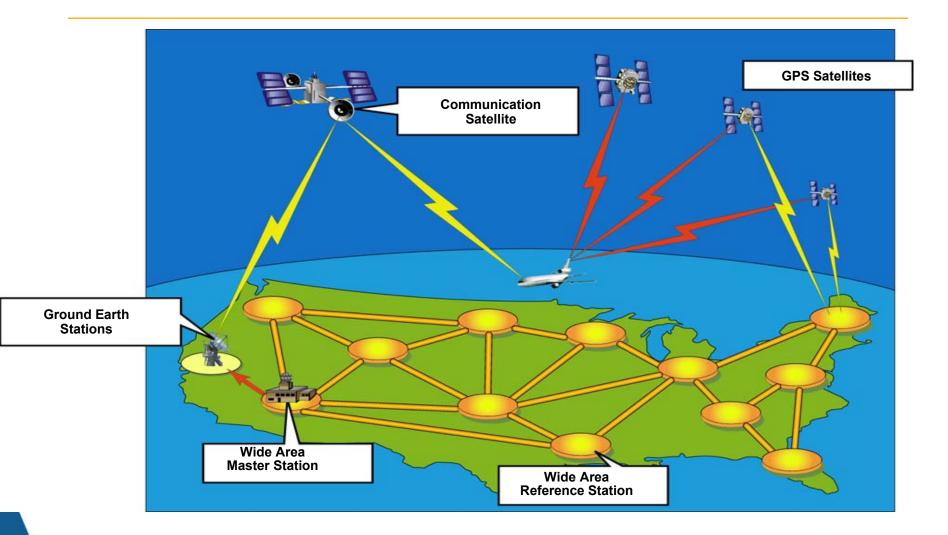
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Wide Area Augmentation System (WAAS)

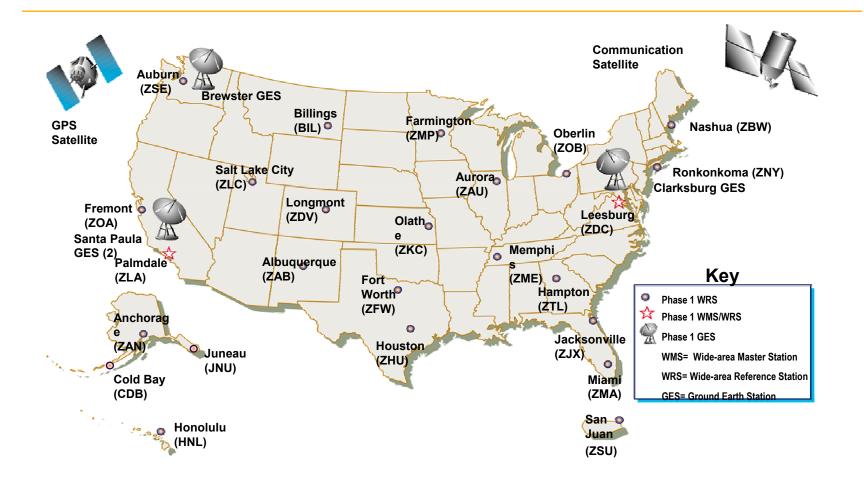






Wide Area Augmentation System

Initial Equipment Locations







WAAS Benefits

- WAAS will provide increased accuracy and availability for navigation throughout CONUS (and much of Alaska), and provide advanced navigation procedures, such as departures and curved approaches
- A significant safety benefit will be the provision of vertically-guided approaches to nearly all runways
 - USA has 5000 airports with at least one runway 3000 ft long
- Initial plans were to provide vertical guidance to Category I approach minima
 - 200 ft Height Above Touchdown (HAT)
 - Integrity re-evaluation in 1999 indicated this goal was overly optimistic for single-frequency WAAS





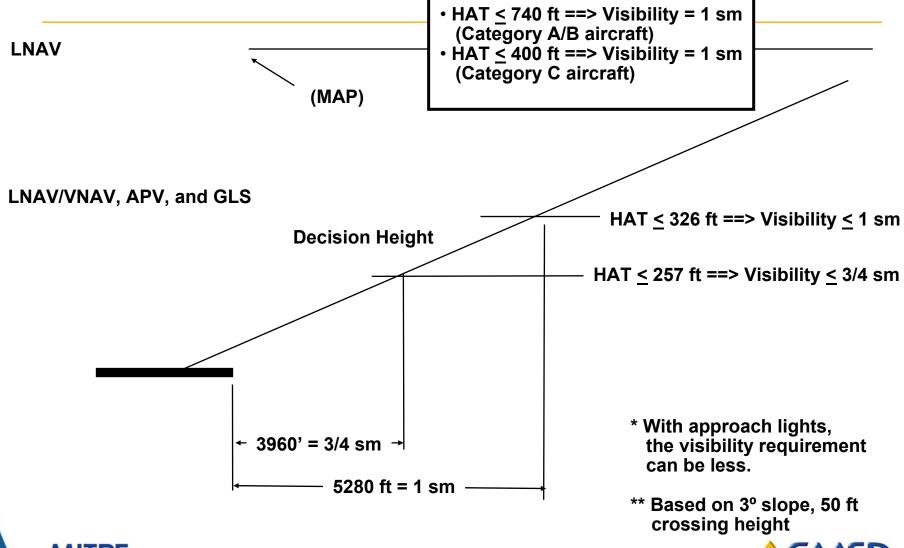
Instrument Approaches

- GNSS Landing System (GLS)
 - Equivalent to ILS Category I approach with lowest HAT of 200 ft and lowest visibility of ½ statute mile
 - Generally not considered possible with high availability for single-frequency WAAS
- LNAV/VNAV BARO/VNAV
 - Originally designed for FMS-equipped aircraft with sophisticated barometric altimetry system
 - Flyable with DME/DME Inertial, GPS or WAAS
- LNAV
 - Nonprecision approach flyable with DME/DME Inertial, GPS or WAAS





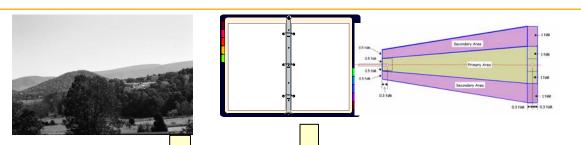
Visibility Values



6

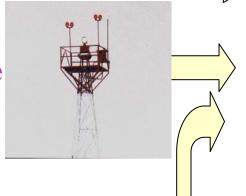
GPS Approach Minima Estimator (**GAME**) **Model**

Terrain
Data Base



Approach Design Criteria

Obstacle Data Base



Minima Estimation Software

Repeat for Thousands of Runway Ends

Airports Data Base



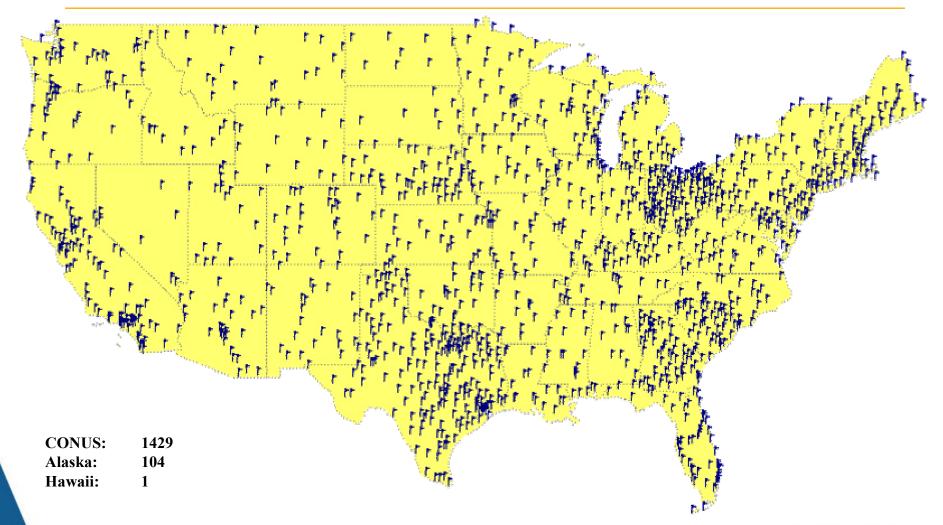
Gen

LNAV/VNAV Visibility - LNAV Visibility (sm

Generate Statistics



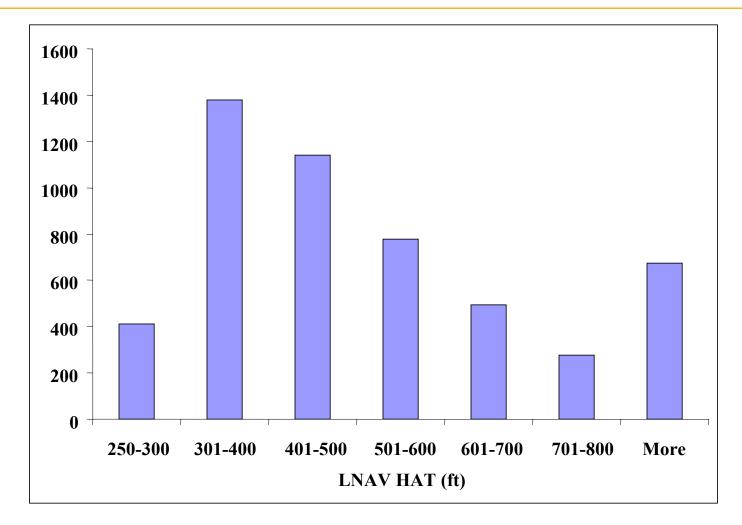
GAME Airports: 1534 airports and 5073 runway ends







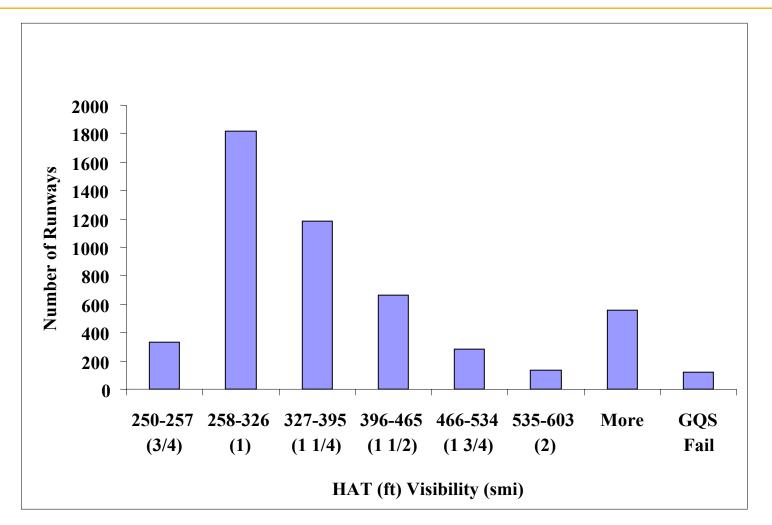
Estimated HAT for LNAV Approaches (Existing Capability without WAAS)







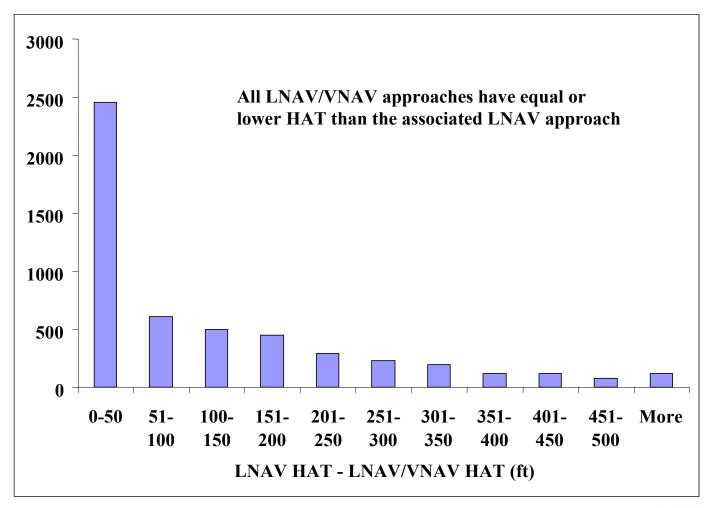
Estimated LNAV/VNAV HAT







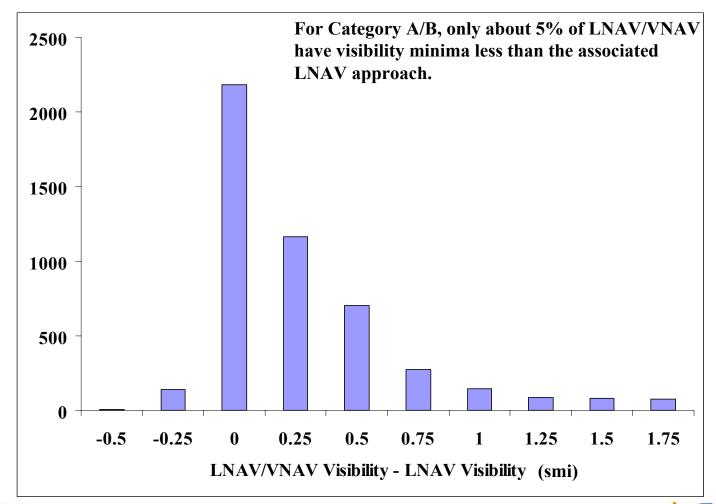
Estimated Improvement in HAT with LNAV/VNAV(Available at WAAS Phase I)







Estimated Visibility Benefit for LNAV/VNAV vs. LNAV (Cat A/B Aircraft)







New Approaches

• To improve near-term instrument approach benefits of WAAS, the FAA investigated instrument approach criteria that used the horizontal and vertical integrity available from WAAS

LNAV/VNAV - RNP .3 (556 m horizontal by 50 m vertical)

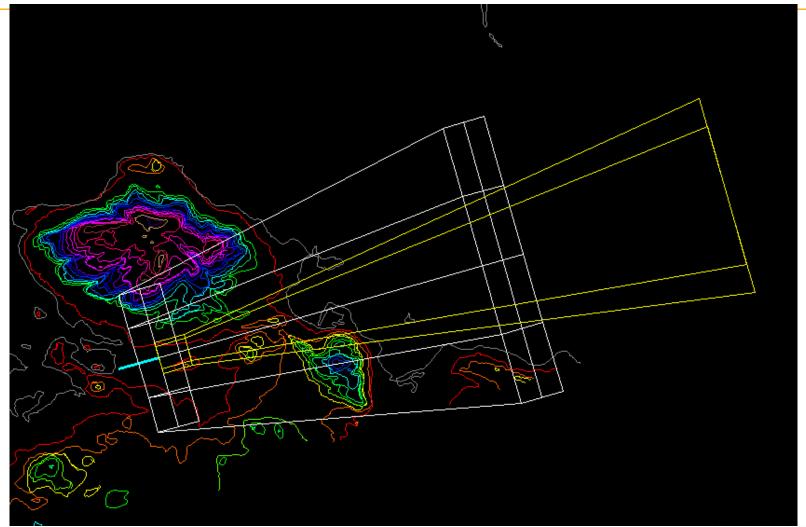
LPV (40 m horizontal by 50 m vertical)

GLS (40 m horizontal by 12 m vertical)





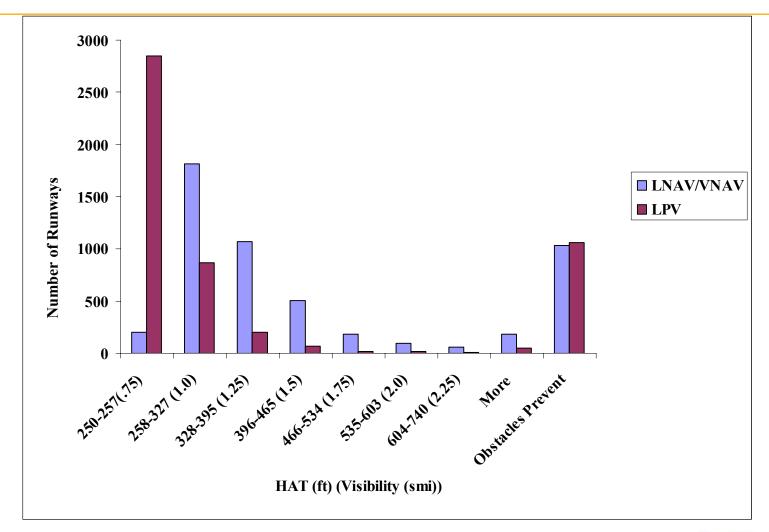
Comparison of LNAV/VNAV with LPV Primary & Secondary Obstacle Surfaces







Comparison of LNAV/VNAV with LPV





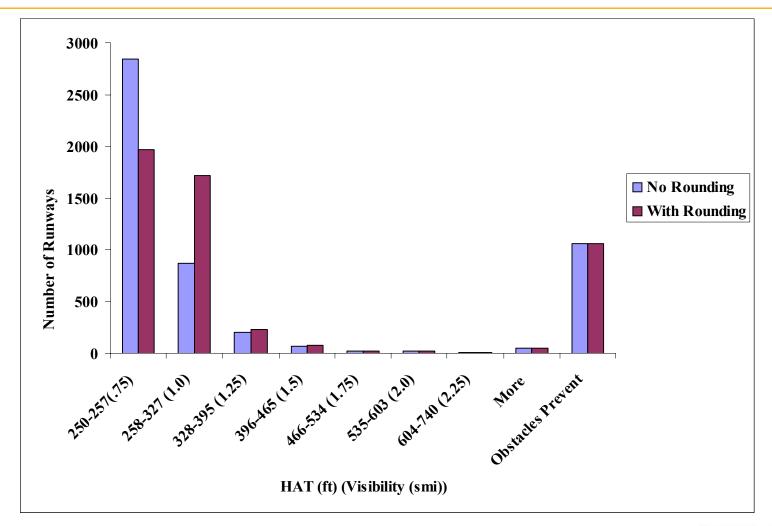


LPV

- Significant increase in capability for no additional investment in WAAS ground facilities
- The FAA has decided to implement LPV
 - First approaches are to be implemented this year
- LPV criteria will be incorporated into ICAO Satellite-Based Augmentation System (SBAS) standards and recommended practices as Approach with Vertical Guidance I (APV-I)



Rounding of HATs







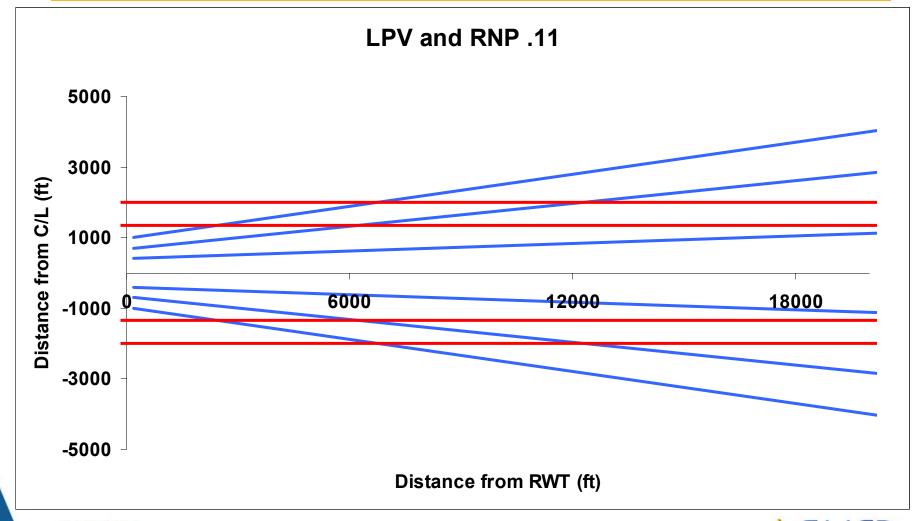
Required Navigation Performance (RNP) Instrument Approach Procedures

- Enhancement to navigation specifying accuracy and containment areas
- For instrument approaches, containment area is generally 2 x RNP value (in nautical miles)
- Provides for rectangular versus trapezoidal obstacle clearance areas
 - BARO-VNAV vertical obstruction areas
- Generally flyable
 - By GPS or WAAS equipped aircraft for RNP .3 or higher
 - By FMS equipped aircraft for all RNP values
 - GPS and inertial often required for RNP \leq .3
 - Specific certification required





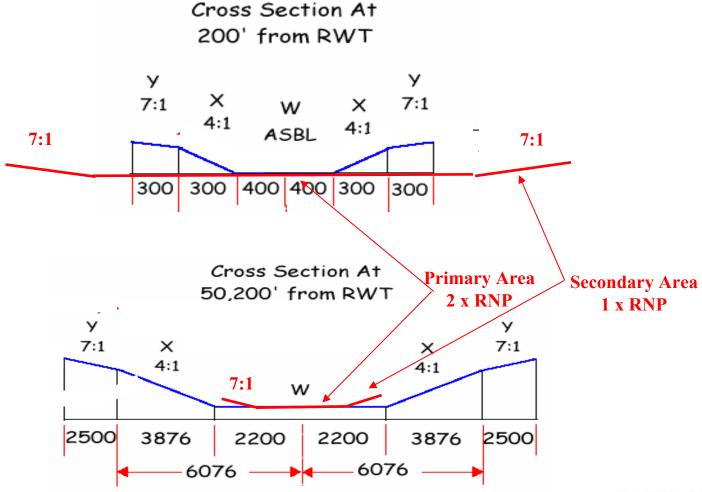
RNP .11 and LPV Horizontal Depiction







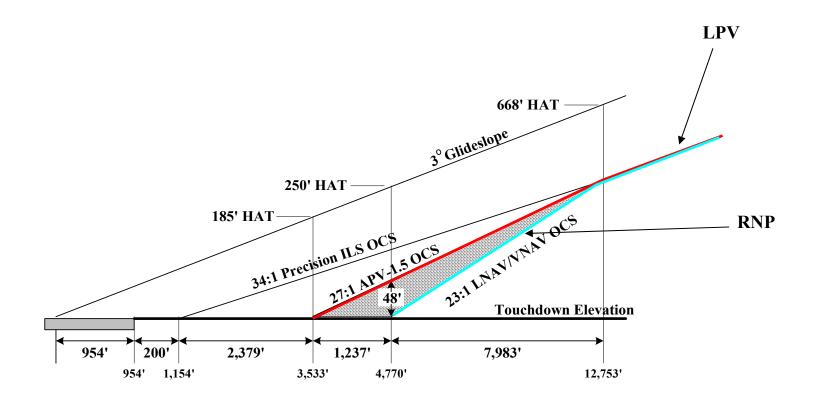
RNP .11 and LPV Draft Criteria Vertical Depiction from End of Runway







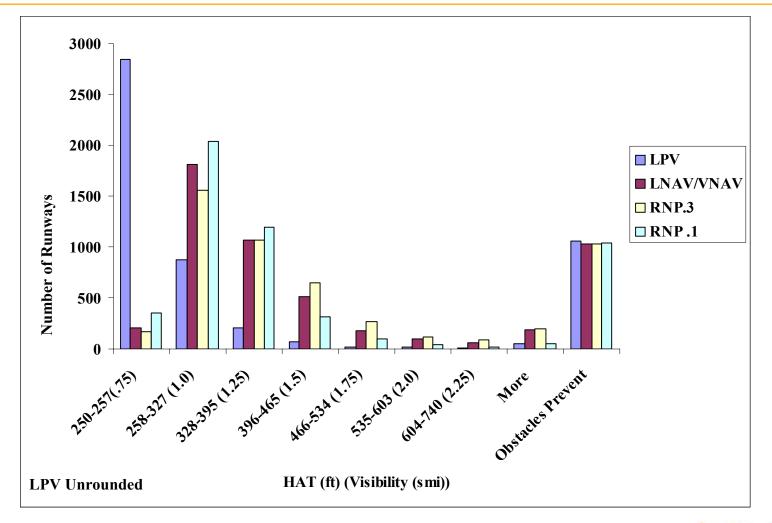
Obstacle Clearance Surfaces Side View







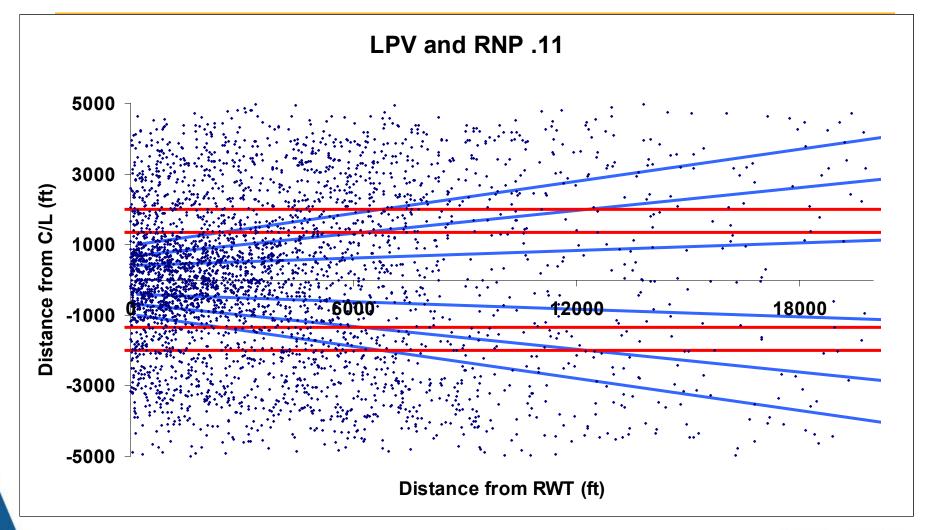
RNP Approaches Versus LPV and LNAV VNAV







RNP .11 and LPV Draft Criteria Depiction with Controlling Obstacles







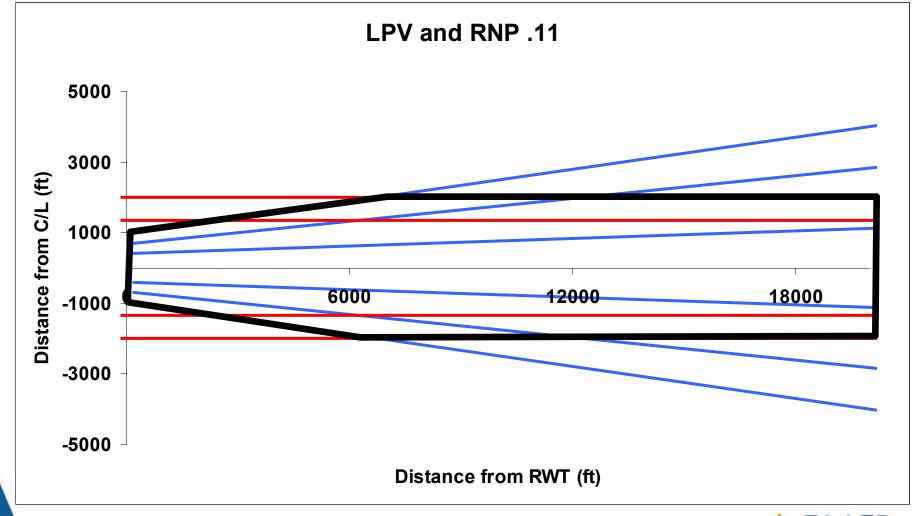
Improving Vertically Guided Approaches

Horizontal Improvement

- LPV obstacle clearance standards are very 'wide' far from the runway, but narrow close to the runway
- RNP are wider near the runway, but narrow far from the runway
- Developed combination approach that uses RNP when far from the runway, and transitioning to LPV as the aircraft approaches the runway



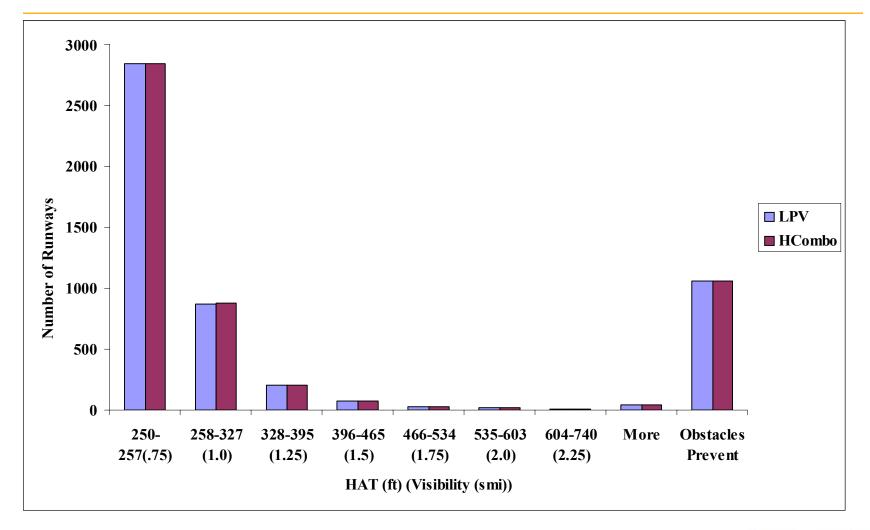
RNP .11 and LPV Horizontal Depiction







RNP/LPV Horizontal Combination (Unrounded)





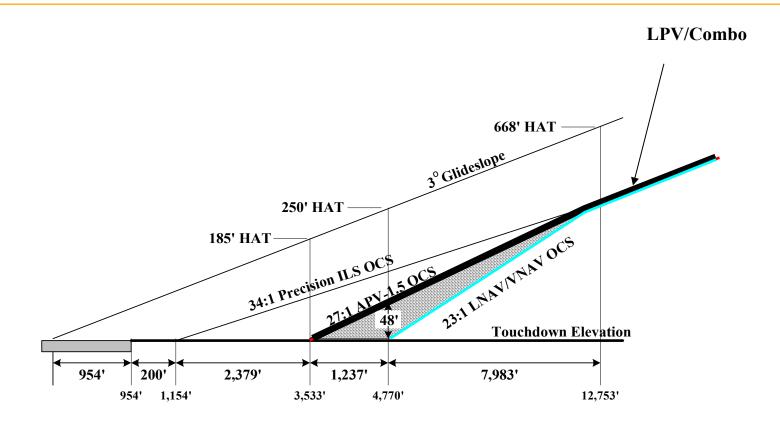


Improving Vertically Guided Approaches

- Vertical Improvement
 - RNP approaches use BARO-VNAV vertical obstacle clearance profiles
 - The BARO-VNAV profile has the same vertical integrity limit as the LPV profile, but is temperature compensated and seemingly more conservative
 - Developed combination approach that uses RNP horizontal obstacle clearance profiles with LPV vertical profile



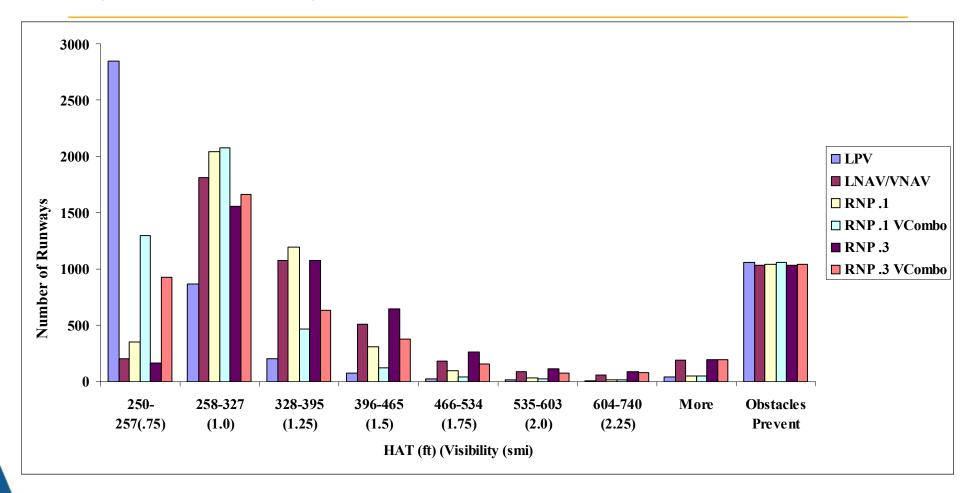
Vertical Obstruction Surfaces







RNP/LPV Vertical Combination (Unrounded)







Observations

- LPV will provide a significant increase in capability for WAAS-equipped aircraft with little cost to the FAA WAAS program
- RNP provides reasonable instrument approach capability for non-WAAS equipped aircraft
 - Minima are not as low as LPV
- Some improvement may be possible for RNP with improved criteria
 - Overall with improved vertical criteria for RNP
 - Airport specific for improved horizontal criteria





Backup Slides



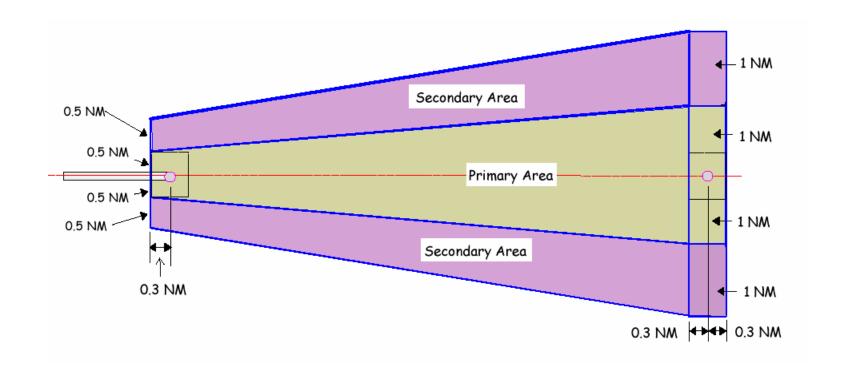
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Abstract

 The WAAS system, which will be commissioned in a few months, will provide the capability for verticallyguided instrument approaches at most runway ends in the continental United States. Different criteria have been developed for designing these instrument approaches. This presentation will provide background on the development of vertically-guided instrument approaches and estimates of the relative benefits provided by several different approach criteria, including the approaches governed by the new Required Navigation Performance (RNP) criteria.



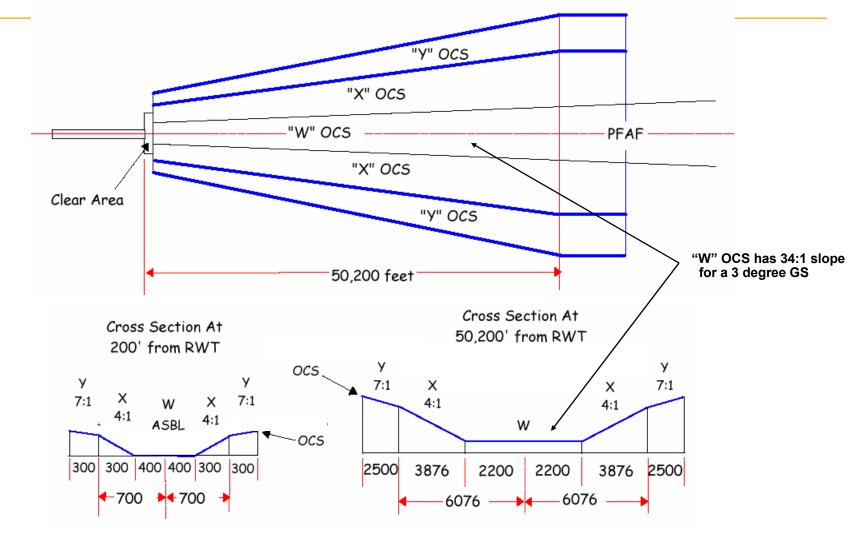
LNAV and LNAV/VNAV Obstacle Clearance Surfaces







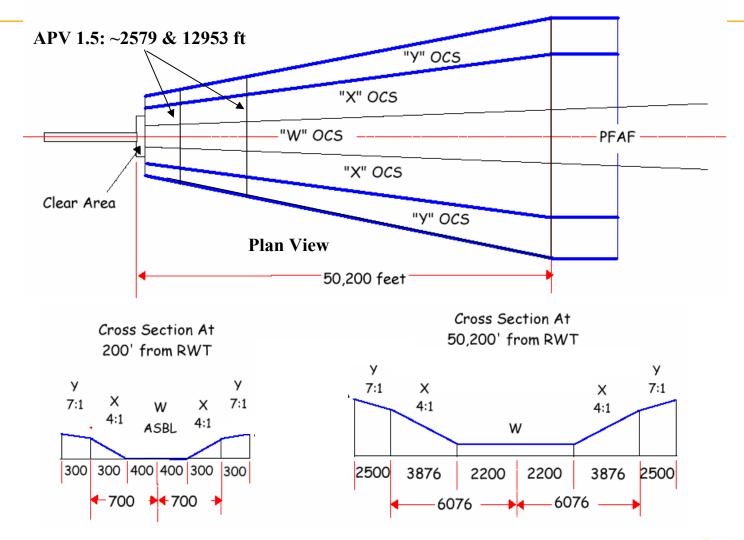
GLS Obstacle Clearance Surfaces







LPV (APV 1.5) Obstacle Clearance Surfaces

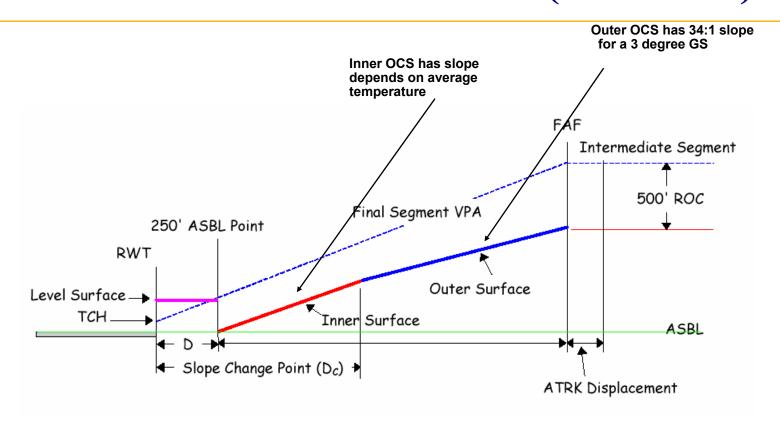








RNP and LNAV/VNAV (Baro VNAV) Obstacle Clearance Surfaces (Side View)

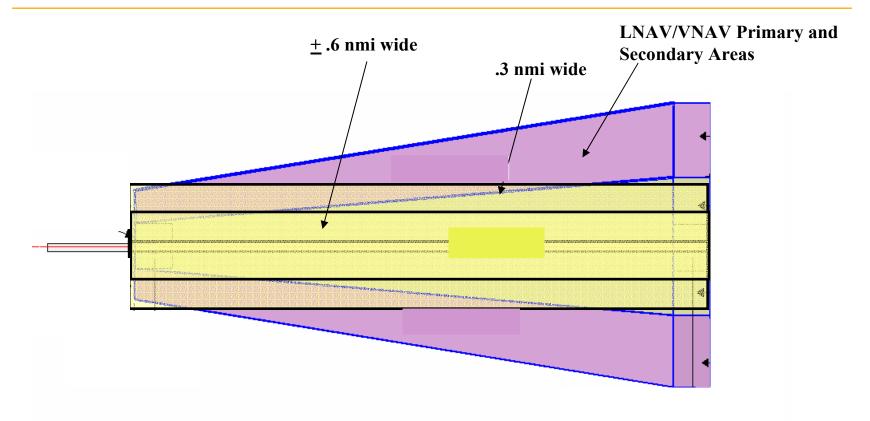


250 ft ROC for the inner surface and inside the 250' ASBL point 250 - 500 ft ROC for Outer Surface





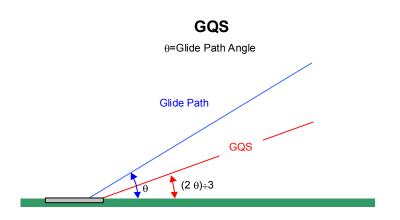
RNP-.3 LNAV/VNAV With Secondary Areas

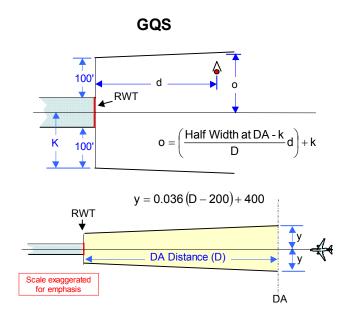






Glidepath Qualification Surface (GQS)





The GQS limits the height of obstructions between the DA point and the threshold. When obstructions exceed the height of the GQS, an approach with vertical guidance is *not authorized*.



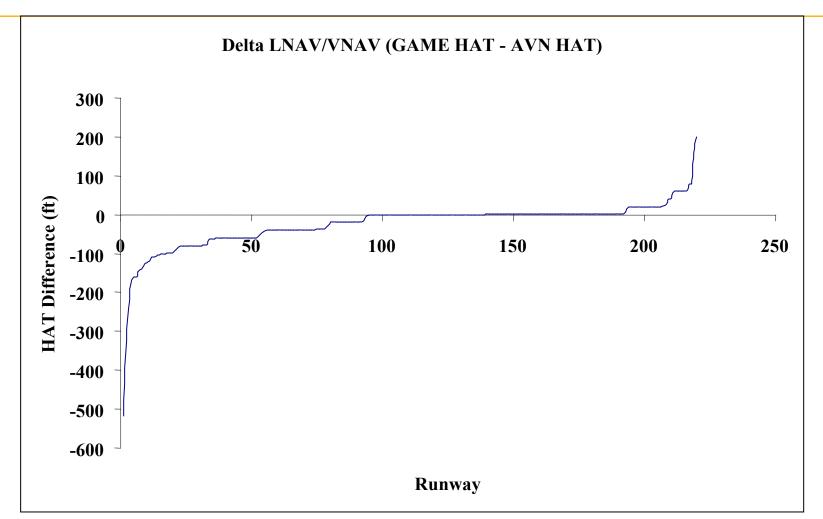


Validation

- Compared GAME HAT and visibility values with 217 LNAV and LNAV/VNAV approaches developed by AVN
- Compared GAME HAT with 849 ILS approaches developed by AVN
- In general, GAME provides a close estimate of HAT (< 50-100 ft) 80 90% of the time)



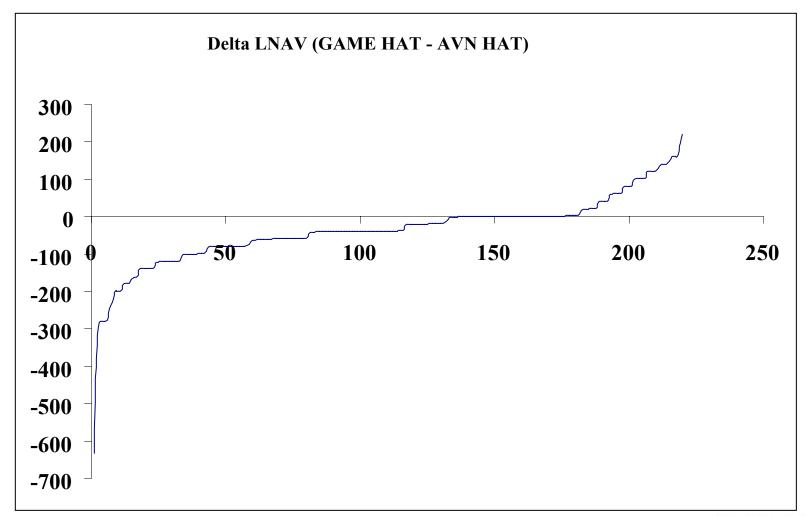
LNAV/VNAV Validation GAME HAT - AVN HAT (n = 217)







LNAV Validation GAME HAT - AVN HAT (n = 217)

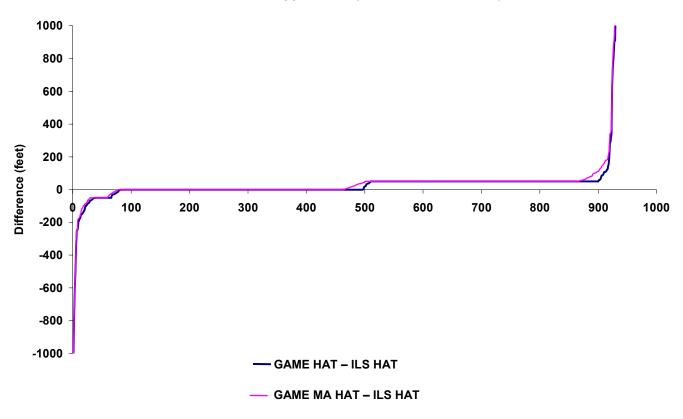






GAME at ILS Runways With and w/o Missed Approach (n = 930)

GLS HAT Delta for 930 Approaches (GAME HAT - ILS HAT)







GLS Validation GAME HAT - AVN HAT (n = 849)

